Master’s Thesis of City Planning

Analyzing the influential factors of the elderly daytime mobility in Seoul

- Using big data of de facto population in Seoul -

서울시 주간 노인 인구 이동성의 영향요인에 관한 연구
-서울 생활인구 빅데이터를 사용하여-

August 2020

Graduate School of Environmental Studies
Seoul National University
Urban and Regional Planning Major

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Abstract

The aging phenomenon is not limited to demographic fluctuations, but it leads to changes in the social structure and the living world, and changes in the consciousness and social structure of the elderly who have been traditionally maintained. As social and economic conditions of the elderly change, recently a new approach to the elderly is spreading due to the increase of young elderly people. However, there is increasing concern that characteristics of population distribution and the factors affecting the elderly population by dividing the aged population over 65 years by age group are different. In the megacities such as Seoul with good public transportation access, mobility restrictions for the elderly are eased, the activity radius is widened, and spatial restrictions on the mobility of the elderly are reduced, increasing the participation rate of economic activities in the elderly and the proportion of leisure activities in the city.

In the meantime, distribution of the residence registration population was taken into account, in this study the spatial distribution of the elderly during the daytime, when leisure and social activities were mainly conducted, was identified. The elderly were analyzed by the Young-old (less than 75 years of age over 65) and the Old-old (75 years of age). The purpose of this study is to analyze the factors affecting the physical environment of the city that affect the mobility of the elderly during the daytime by subdividing into the above.

The study hypothesized that factors affecting the mobility of the elderly during the daytime hours will be different depending on the age group, and more active leisure services affect the Young-old.

Spatial regression model analysis was used based on the data of the Seoul de facto population. In 2018 The general regression model was set as the baseline model for analysis, and the spatial lag model (Spatial Lag Model) and spatial error model (global error model) were set as alternative models. As a result of the model analysis, the factors that increase the mobility of daytime Young−old are general social welfare facilities, general hospitals, traditional markets, public sports facilities, road ratio, commercial area ratio, and the number of elderly people at nighttime. Elderly welfare facilities, traditional markets, commercial areas, and the number of elderly at nighttime were found to increase Old−old. These results can be seen as reflecting the preference of age−integrated facilities for the Young−old and the Old−old who prefer elderly−centered welfare facilities. In addition, the travel radius of the elderly is wider in the case of Young−old, and the study suggested a specialized leisure activity program to activate their new leisure culture.

This study identified the research hypothesis by confirming that there were differences in urban environmental factors affecting the mobility of the elderly. New attempt to find ways to improve activity data of the elderly population by utilizing the de facto population that reflects the flow of the real−time population. It should be considered to prepare policy implications for the subdivided elderly in an aging−friendly society.

Keywords : elderly de facto population, daytime mobility, affecting factors, leisure activities, spatial regression model

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Chapter I . Introduction

1. Research Background

Population aging is a universal trend in the demographic structure of developed countries, and this global aging trend is progressing rapidly. The aging phenomenon is not limited to demographic fluctuations, but it leads to changes in the social structure and the living world, and changes in the consciousness and social structure of the elderly who have been traditionally maintained. One of the most important criteria for the aged society is that the age definition of the elderly. To date, the elderly commonly referred to as people above the age of 65. However, as social conditions change, the consciousness, conditions of health, and lifestyle change as well. In this aspect, there is increasing concern that characteristics of population distribution and the factors affecting the aged population by dividing the elderly population over 65 years by age group are different. Therefore, a new attempt to divide old age has been made in a study of the elderly(Lim&Kim, 2012; Go&Lee,2017; Gang&Namgung,2018; Lee, 2019).

Meanwhile, spatial constraints for the elderly living in Seoul had been reduced due to improved public transportation accessibility and subsidy policies. This causes a difference between the place of residence and the actual area of activity. In order to provide the facilities and services that meet the daily needs of the elderly in space, the elderly population in the daytime when activities of the elderly are mainly performed was considered.

In 2008, 15.9% of the elderly in Seoul used the elderly welfare center for the elderly, but it decreased to 11.5% in 2011 and 9.4% in 2017. Also, in response to the intention of the elderly living in Seoul to use the elderly welfare center, it was 46.4% in 2008 but decreased to 29.7% in 2017. As the economic and health conditions of the elderly increase and many organizations provide services similar to the welfare centers for the elderly, the desires have diversified and the choice of various institutions besides welfare facilities has expanded. In other words, the urban environment established before the aging society does not reflect the new aging trend of diversified service demand for the elderly.

World Health Organization(WHO) has pointed out 'Age−friendly City' as a city that realizes active aging[①] with the goal of building a human−friendly urban environment (WHO, 2007). Joining WHO's Global Network of Age−Friendly Cities and Communities(GNAFCC) in 2013, the Seoul Metropolitan Government is providing support for the various elderly population with the slogan of Age−Friendly Seoul, but studies considering the de facto population were not sufficiently covered. Therefore, the 'long−life society' is considered not only with adding years to life, but also with an 'elderly people−friendly' environment that can help the elderly maximize mobility and access to various opportunities and services.

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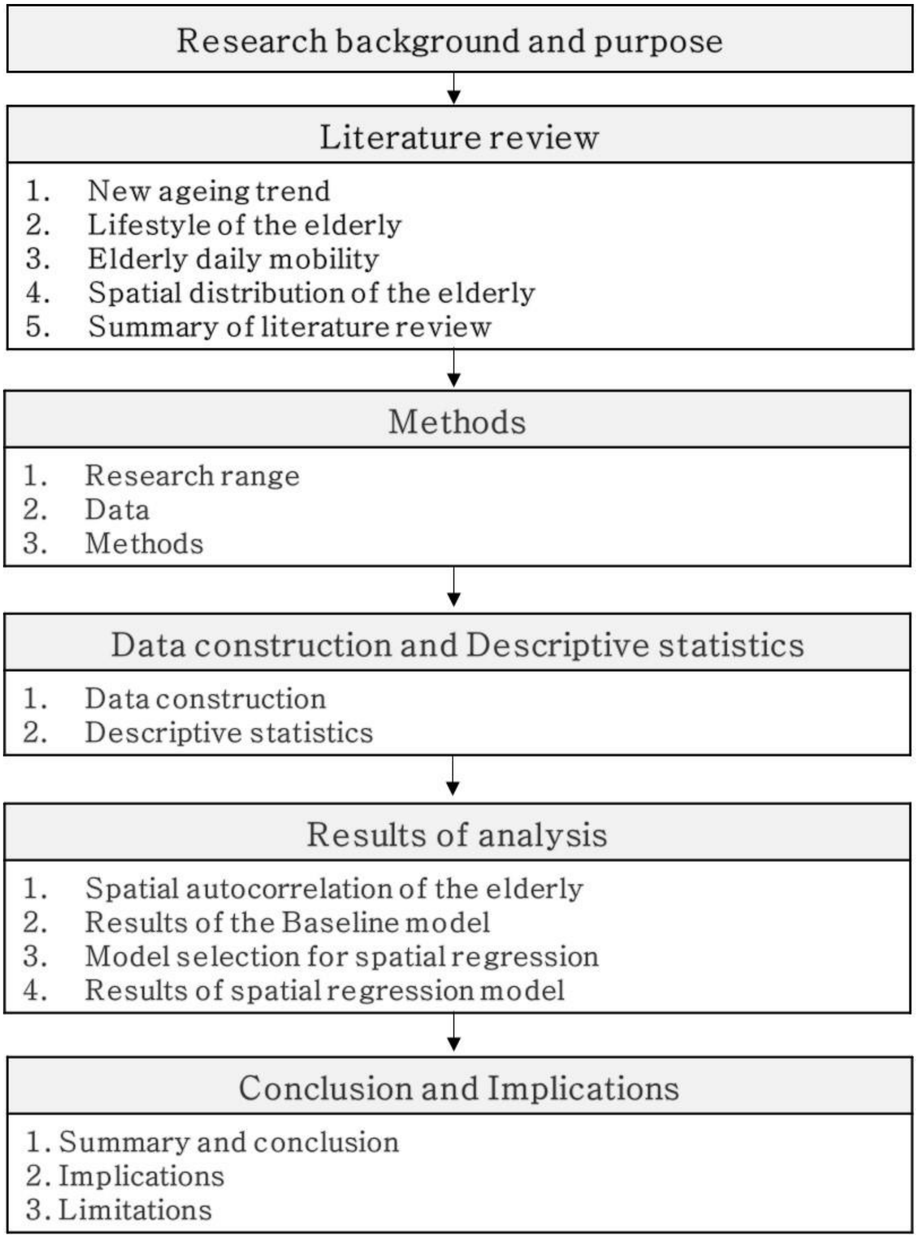
① Active ageing is the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age(WHO, 2002)

2. Purpose of Research

The purpose of the thesis is to analyze the spatial distribution of the elderly population during the daytime, where leisure and social activities of the elderly are mainly performed, and to identify the factors affecting the daily mobility of the elderly. The detailed objective is to analyze the status of the urban environment factors for diversifying services by age group. The study contributes to a better understanding of the daily aspects of the elderly population informs urban welfare policymaking for the new aging population.

3. Thesis Structure

The thesis consists of six chapters as shown in [Figure 1.1]. In the chapter of introduction, the study aims to examine the spatial distribution of the elderly population during the daytime and to identify the factors affecting the daily mobility of the elderly. In the literature review, the theoretical backgrounds and previous reviews were studied related to the elderly daily mobility to derive implications and differences in the research. In the third chapter, the research range, data, and research methodology are explained. Chapter four presents the data construction and descriptive statistics of the study. In chapter five, the alternative model is analyzed through the baseline model analysis and diagnostics, and the optimal model is selected for the analysis of elderly daily mobility characteristics through the goodness−of−fit of the analysis results. Lastly, chapter six summarizes the analysis results and presents policy implications and limitations of this study on the characteristics of mobility in the elderly in Seoul.



[Figure 1. 1] Research flow chart

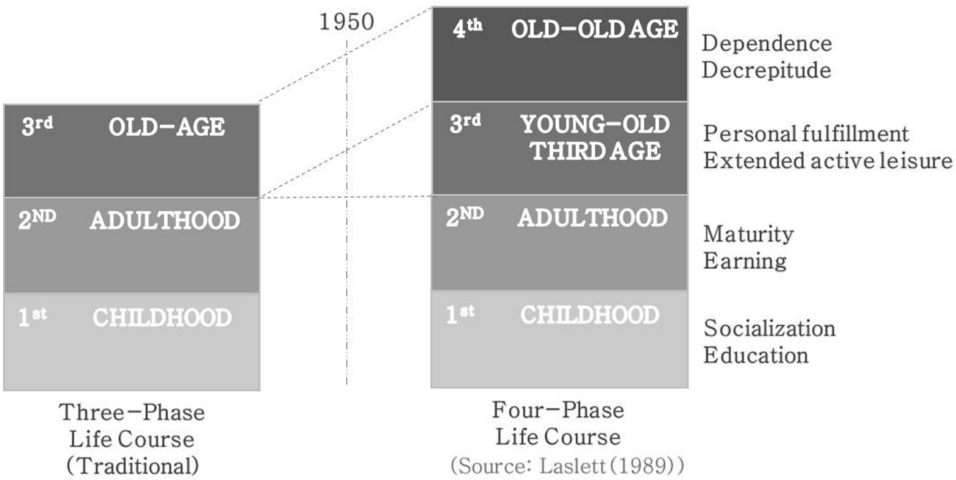
Chapter Ⅱ. Literature Review

1. New aging trend

Urban aging deals with both the aging of the population and living in cities. The aging of society is a positive yet challenging phenomenon. By treating the place as a mere 'container' and 'old people' as a homogeneous category, there can be inadequate recognition of diverse needs (Wiles et al., 2012)

Since the mid-1970s, many changes have occurred due to high unemployment and increased labor market flexibility. In this process, differentiation occurred in older age groups. In other words, the third age[②] was created between the time of work as the second age and the time of mental and physical decline as the fourth age (Laslett,1991; Gilleard& Higgs,2013 Wiles et al., 2012). This period is a vague and flexible stage of life between labor and leisure, and the absolute age rules vary depending on people and a loose social system is applied. Torres-Gil (1992) identified the three aspects of the policy for the elderly in an aging society: a surge in the size of the elderly population, diversity of the elderly population, and a national financial crisis related to the elderly policy. Therefore, the basis for socially common norms, roles, and behaviors should be defined for these age classes or age groups.

② Gilleard& Higgs(2014) describes 'the third age' to define a new stage of life characterized as an era of personal fulfillment and 'the fourth age' as a period of dependence, decrepitude, and death



[Figure 2. 1] Emergence of Young-old

2. Leisure place selection of the elderly

In general, individuals in old age have increased leisure time after retirement, but the increased leisure time of the elderly is a large part of the increase in rest time. Compared to the growing amount of leisure time, qualitative improvement is not significant. In this context, the elderly's space, such as the senior centers or the elderly welfare center, can be regarded as a space prepared by the society to accommodate the elderly. However, the elderly in Korea spend most of their time at home, rather than participate in active forms of leisure activities that involve active physical activity, and most of them are filled with passive activities such as watching TV(Lee et al., 2005; Chung et al, 2017). According to a study conducted by Hong (2018), which surveyed 67 elderly people at Mangwon-dong in Seoul, the average time spent at home for one day was 17 hours and 15 minutes, and 6 hours and 45 minutes outside the home. The probability of going out around 3 pm to 4 pm was the highest. Han&Lee (2015) analyzed the purpose of public transportation travel by elderly and travel is relatively distributed from 6 am to 6 pm, and peak hours are 9 to 11 am and 3 to 5 pm. The main leisure activities performed outside are social activities such as social volunteering activities and visits to family and relatives are the highest at 34.9%, followed by walking (27.5%) and sports participation activities (16.6%)(Chung et al. 2017). Kim&Kang (2017) divided the elderly leisure facilities used by the elderly in urban areas into five, with the highest number of senior center users at 59.4%, the elderly welfare center (32.2%), welfare institution (24.5%), public leisure facilities (13.1%), and followed by private leisure facilities (5.3%).

However, the elderly people’s perceptions and utilization rates of the elderly welfare centers, which are representative of welfare facilities for the elderly, are changing. The response to the elderly's intention to use the elderly welfare center in Seoul was 46.4% in 2008 but decreased to 29.7% in 2017. In the case of the senior center, the perception of the senior center is high, but compared to the elderly welfare center, relatively older age groups prefer to use senior centers. The desire to use senior center is gradually decreasing as the age decreases (Hong&Kim, 2016). The reason why there is no intention to use the facility is that there is no peer of the same age (37.2%), and there is no program to participate (25.3%). Thus, it reflects the different needs of the facilities and service programs between different ages.

3. Elderly daily mobility

Mobility patterns of the urban population are the process by which people living in cities visit places where activities related to their daily lives are located. Urban mobility can be grasped by using the activity spaces that make up the daily lives of urban residents and traveling through them (Lefebvre, 2004). As information technology and various smart media have been incorporated into urban space, various time and space information about cities has been generated and accumulated, and the possibility of various time and space analyses of urban spaces is increasing (Park&Lee, 2007). Likewise, the mobility of the elderly has been studied by observing the elderly's location in each space and time.

1) Factors affecting the elderly daily mobility

Along with the rapid increase in the number of the elderly, the daily mobility patterns of senior citizens are becoming more diverse. Some characteristics of elderly travel behaviors are distinguished from other age groups. While non-elderly people who engage in economic activities accounted for more travel for work than other purposes, elderly people who already retired were actively engaged in non-working activities such as shopping and leisure.

Researchers attempted to evaluate the factors of the daytime activities of the elderly using time-separated data. Han&Lee (2015) analyzed the characteristics of the time-based travel flows for the elderly in the Seoul metropolitan area. While between 9 am to 12 pm, the main factors of travel destinations were the number of hospitals, elderly welfare facilities, traditional markets, parks, CBD areas, and Gangnam. Yi & Choi(2018) used the de facto population to identify the spatio-temporal distribution of the elderly in Seoul dividing the daytime and nighttime, weekdays, and weekends. This noted the determinants based on the hotspot areas of daytime, which were derived from 11 am to 4 pm. Accessibility of hospitals, subway stations, and buses was shown to have positive impacts on the daytime concentration of the elderly. The senior centers and neighborhood parks have negative impacts, which were interpreted that the elderly's demand for those facilities within walking distance.

To date, most of the research on the travel and spatial distribution of the elderly mainly considered as one group. However, some studies (Kim et al., 2012; Go&Lee, 2017; Kang&Namgung,2018) that segmented the elderly indicated different travel factors depending on the age group of the elderly, reflecting differences in physical and economic abilities within the elderly generation. Kim et al. (2012) conducted an interview survey of elderly people aged over 65 living in Seoul, indicating that the impact of public transportation is different depending on the area surveyed. Factors affecting the mobility of the elderly people in the study showed that the older the age, the more difficult it is to access public transportation. Also, when senior centers and parks were located within the pedestrian area of the elderly, it was less restricted to travel to use those facilities. Go&Lee (2017) analyzed the factors affecting the ratio of non−working travel patterns of the elderly in Seoul by subdividing the elderly group like 65 to 69 years old, 70 to 74 years old, and 75 to 79 years old. The number of employees on the leisure shopping industry and the density of the floating population were found to increase aged 65 to 69, while the elderly welfare facilities and density of the floating population were found to decrease aged 70 to 74. Cultural history parks lead a positive effect to age over 75, while floating population density cause negative effects. For the regional factors, those aged 65 to 69 and those aged 70 to 74 were affected by variables that could explain in CBD areas, while those aged over 75 were affected by residential districts or neighborhood areas, suggesting differences in travel characteristics by age groups. Kang&Namgung (2018) also identified factors affecting the use of public transport from the non−working of elderly people aged over 65 and found that the older the age, the more negative impact on the use of public transportation, the more hospitals, markets, bus stops, and the number of leisure facilities for senior citizens showed a positive impact. Besides, when the elderly population is subdivided into the young−old(65−74 years old) and the old−old(over 75 years old), the affecting factors differed by two elderly groups. The number of hospitals and bus stops has a positive impact on the young−old, and the number of elderly leisure facilities has a positive impact on the old−old.

[Table 2. 1] Previous studies on the factors affecting the elderly

Author (year)	Study area	Dependent variable	Independent variable
Kim et al. (2012)	Seoul metropolitan area, Korea	Lack of perception on public transportation by the elderly (65+)	Age(+), physical disability(+), transportation accessibility(−), slope(+), social platform(−), sense of community(−)
Han &Lee (2015)	Seoul metropolitan area, Korea	Travel flows of the elderly from 9 am to 12 pm	Hospitals(+), elderly welfare facilities(−), traditional markets(+), parks(+), CBD area(+), Gangnam area(+)
Go&Lee (2017)	Seoul, Korea	Non-commuting travel of the elderly	Employees on leisure &shopping industry(+), employees on health&welfare industry(+), traditional market(+), oriental hospital(+), floating population density(+), history culture park (+), Number of cars available for parking(+)
Kang& Namgung (2018)	Seoul, Korea	Public transportation usage of the elderly	Age(−), income(−), Job status(−), car ownership(+), number of bus stops(+), subway accessibility(+), commercial area ratio(+), markets(+), hospitals(+), elderly welfare facilities(+)
Yi&Choi (2018)	Seoul, Korea	Elderly daytime hotspot area	Accessibility of medical centers(+), senior centers(−), small park(−), neighborhood park(−), subway(+), bus stop(+)

2) Measuring the elderly mobility

Attempts have been made to measure the elderly behavior of location choice. When the mobility of the elderly is divided into housing, transportation, and daily mobility, the data considered to analyze it also changes. Urban dynamics are more complex with high flexibility and require a new method of analysis (Ratti&Frenchman,2006). Depending on the data acquisition, empirical studies on elderly mobility have been conducted on various scales as shown in [Table 2.2] below.

First, static sociodemographic census data and migration data were used to analyze the elderly's housing choice. Census data is possible for a complete enumeration, but the cycle of the investigation is too long and costly. And migration data provides information on elderly population influx and outflux, whereas the research costs too much and uses aggregated data.

Second, travel survey data and travel purpose Origin-Destination (O-D) have been used for the study of elderly people's travel choices. This section focuses on their travel pattern or modal choice instead of the actual location of the elderly population. Travel survey data enables a collection of the desirable data of participants' travel activities, such as departure time, arrival time, public transportation transfer, and so on. But there are temporal and economic constraints of performing the survey. And travel purpose data provide mobility of the elderly classified by the 'purpose' of the trip as well as the location of O-D of the elderly. But this data has limited spatial and temporal details.

Recently, for the daily mobility pattern of the elderly, Global Positioning System (GPS) information and cell phone signal tracking data are used. Using advanced collecting technologies can save time and reduce the costs of collecting data, providing researchers with more accurate and comprehensive information (Lee et al.). And the results can be seen in a graphic representation of the elderly people's activity and intensity through time and space (Ratti&Frenchman,2006). In the case of GPS data, the characteristics of walking activities of the elderly are identified through the information collected through sensors in special equipment or a smartphone application and it enables to provide precise location-based information and the complete movements of the elderly. However, there is a limitation of collecting only sampling data representing a small portion of the population (Hong, 2019; Jeong, 2020). Furthermore, cell phone signal tracing data is routinely collected from the mobile phone network, as location-based time series data can give spatiotemporal locations of elderly population and activity patterns (Yi&Choi, 2018). Studies on the activity of the elderly population using mobile data is a field of research with a lot of potentials to utilize it into a real-time activity of the elderly along with the amount of big data accumulated. However, there is a limitation of mobile subscriptions because data collection is confined to cell phone users.

[Table 2. 2] Previous studies on measuring the elderly mobility

Type	Data required	Strength	Limitation	Studies
Housing choice	Census	Complete enumeration	Expensive budget and long cycle of investigation	Jeong&Jeon (2013)
	Migration data	Provide information on population influx	Expensive budget and aggregated count	Duncan; Hong&Yu(2012)
Travel choice	Travel survey data	Enable research design to collect desired data	Temporal and economic constraints	Szeto et al. (2017), He et al.(2018), Kwok (2009)
	Travel purpose O-D data	Collect the purpose of travel information	Limited spatial and temporal details	Han&Lee (2015), Go&Lee (2017)
Daily mobility pattern	GPS or individual-level trajectory data	Location-based data, detailed walking activities and range of activity	Expensive equipment and limited to sampling data	Hong(2019), Jeong et al.(2020)
	Cell phone signal tracing data	Location-based data, routinely collected from the mobile phone network	Limitations of mobile subscription (confined to cell phone user)	Ratti&Frenchman (2006), Yi&Choi (2018)

4. Spatial distribution of the elderly

In the Tobler's first law of geography (Tobler, 1970), 'everything is related to everything else, but near things are more related than distant things' explains the concept of spatial autocorrelation. In other words, the closer they are to space, the more similar they have to each other and the more correlated they are. Spatial autocorrelation usually appears in space as an aggregate or cluster.

Most research on the spatially correlated areas among the elderly population has been carried out extracting spatially autocorrelated areas (Jeong&Jeon,2013; Lee et al., 2015; Park&Lim, 2017; Yi&Choi, 2018). Jeong&Jin(2013) examined the spatially concentrated area in Seoul metropolitan area using hotspot analysis and the elderly's spatially autocorrelated pattern was concentrated in Central Business District(CBD) area in Jung-gu to the northern area of Seoul. Lee et al. (2015) compared spatial distribution patterns of the highly concentrated districts of the low-income elderly in three-year 2000, 2005, and 2010 and it also found there is low income elderly's concentration in Gangbuk(northern area) of Seoul. Park&Lim (2017) analyzed the spatial autocorrelation of the elderly population ratio in South Korea, and a Global Moran' I in

dex was 0.42, which shows a high spatial autocorrelated pattern. And the extracted spatial patterns had strong spatial clusters in the Gangbuk area. Yi&Choi(2018) analyzed spatio-temporal distribution of the elderly de facto population in Seoul by distinguishing daytime and nighttime. There was strong spatial autocorrelation mainly under Han river areas like Gangnam-gu, Seocho-gu, Yeongdeungpo-gu, Yongsan-gu, and Gwanak-gu during the daytime, while the hotspots during the nighttime had a more scattered pattern all over the city.

5. Summary of literature review

According to previous studies (Hong, 2019; Han&Lee, 2015), it was found that the elderly's outdoor mobility activities were concentrated during the daytime. Along with the rapid increase in the number of the elderly, the daily mobility destinations of the elderly are also becoming more diverse. Therefore, the study was conducted with a focus on the daytime leisure and social activities of the elderly.

Most of the studies on the characteristics of the elderly were related to the choice of residential(Jeong&Jeon,2013; Duncan; Hong&Yu, 2012) and transportation(Szeto et al.,2017; He et al.,2018; Kwok,2009). Recently, the study on the daily active area of the elderly was proceeded (Yi&Choi, 2018). As the activity radius of the elderly increases, the residential area and the active area differ in some areas (Yun&Moon, 2018). Yi&Choi (2018) conducted a study of day and night concentrated areas for the total elderly using the de facto population. And from the previous studies that classified the elderly by age(Fobker&Grotz,2006; Choo et al., 2013; Go&Lee, 2017; Namgung et al., 2017; Kang&Namgung, 2018) identified the differences in welfare service demand and travel characteristics by age.

Therefore, in order to reflect the mobility of the population, it is necessary to research the daytime mobility patterns of the elderly by using the de facto population data. This study compared the spatial distribution characteristics between the young−old(aged 65−74) and old−old(aged over 75 years) and identified the welfare service and urban environmental factors that affect the daily lives of the elderly. In particular, variables of facilities that can reflect the demand of the elderly population by age group were considered.

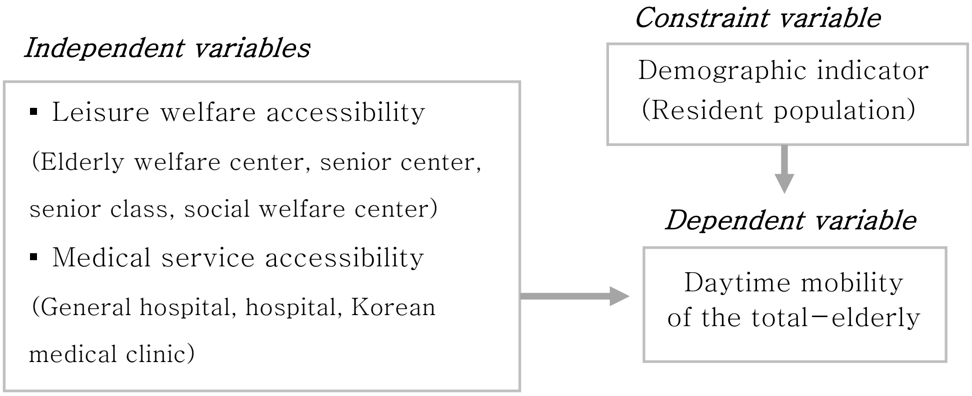
6. Research Hypotheses

This paper attempts to examine the following research question: ***Which factors make difference in daytime mobility within the elderly?***

The factors affecting the daytime mobility may vary depending on their ages within the elderly, which is classified into Young−old aged 65−74 years old and Old−old aged over 75. Therefore, the study aims to compare the characteristics of mobility between non−aged and elderly people and to examine the characteristics of factors between the Young−old and the Old−old.

This research examines the three hypotheses about the characteristics of each age group:

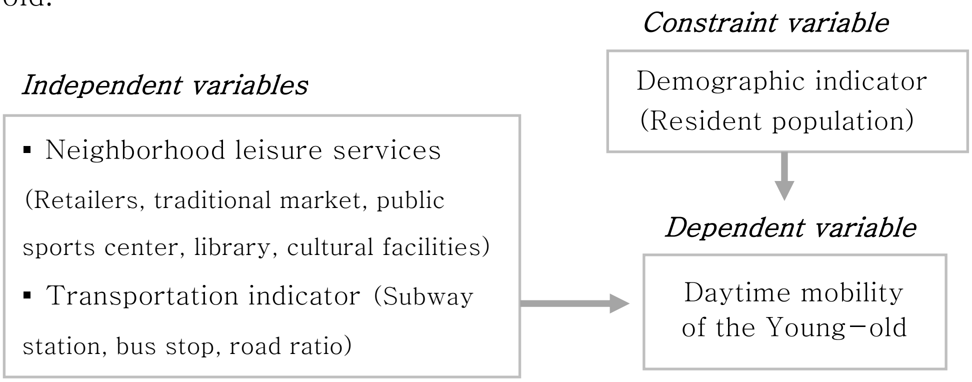
Hypothesis 1. Leisure welfare accessibility and medical service accessibility positively affect the daytime mobility of the general elderly.



[Figure 2. 2] Research hypothesis for the elderly

Hypothesis 2. Young−old has a much larger active radius than Old−old.

Hypothesis 3. Active leisure services positively affect Young−old.



[Figure 2. 3] Research hypothesis between the Young−old and Old−old

ChapterⅢ. Methods

1. Research range

1) Research area

The spatial area of this study is the megacity, Seoul, which also entered 'the aged society'[③] at the end of 2018(SMG, 2019). The total number of people living in Seoul is decreasing, but the elderly population is rapidly increasing. Between 2005 and 2018, the elderly population increased by about 710,000, from 7.3% in 2005 to 14.4% in 2018. And it is expected to enter "the super-aged society" in 2027.

[Figure 3. 1] Seoul's aging progress and prediction

Seoul has higher accessibility to public transportation such as the number of subway stations, and bus routes compared to other

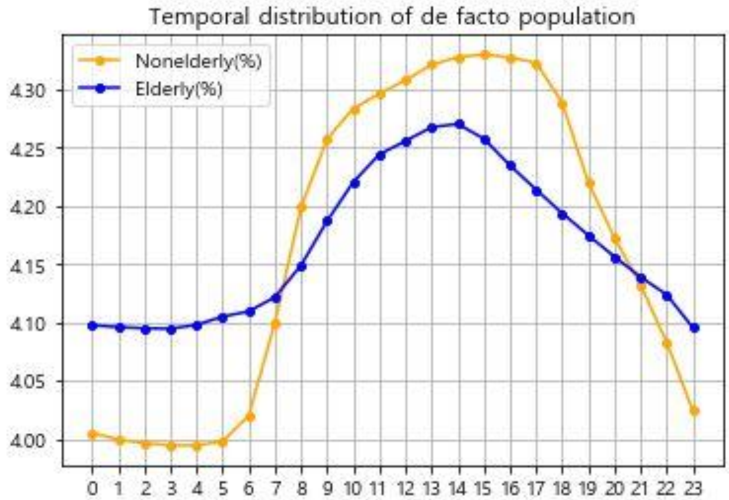
③ According to the United Nations(UN), when the percentage of aged over 65 exceeds seven percent of total population, it is defined as 'aging society', if it's more than 14 percent, it is defined as 'aged society', and more than 20 percent, 'super-aged society' regions. Also, the convenience of transportation by the elderly is being improved through the free ride of the subway and the discount system for the elderly.

2) Unit of analysis

For the unit of analysis, 424 administrative Dong of Seoul is set as a spatial unit. From the service delivery system, the minimum unit of an area in which the level of welfare demand and welfare supply can be measured is the administrative dong unit (Jung et al., 2015). Furthermore, the policy enforcement units of the Seoul Metropolitan Government's core projects, such as community care, visiting community centers(찾아가는 동주민센터), and care SOS centers(돌봄 SOS 센터), are gradually changing from Gu districts to the administrative dong unit (Yun&Moon, 2019).

[Figure 3. 2] Map of 424 administrative dong, Seoul

The temporal scope of the study is from 1st January to 31st of December in 2018 in consideration of the latest data acquisition of independent variables to explain the elderly population. And Temporal unit is an hourly basis. Setting the range of the daytime and nighttime of the elderly population is one of the big issues for the analysis. The distribution of the population that is active in urban space varies depending on the time zone, which may result in sensitive changes in their characteristics of behaviors. As shown in [Figure 3. 3], the time zone with the largest elderly population ratio is between 2 pm and 2:55 pm[④], and the lowest between 3 am and 3:55 am.

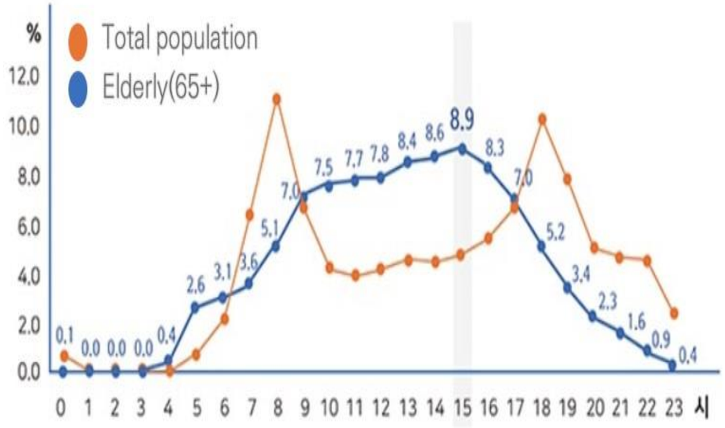


[Figure 3. 3] Temporal distribution of de facto population

Also, [Figure 3. 4] shows the temporal rate of transportation usage comparing the elderly and the total population. This figure

④ The time zone unit of the living population data is an hour interval, meaning 0 o'clock is the time range aggregated between 0 and 0:59.

presents the status of use from 4 to 10 of March 2018, utilizing free transportation transaction card data which is provided for the elderly in Seoul. For the total population, usage of public transportation during rush hour is the peak, while the elderly's public transportation usage is increasing during daytime hours, the highest between 12 pm and 4 pm.



(Source: Seoul Metropolitan Government)

[Figure 3. 4] Comparison of the usage of transportation cards between the total population and the elderly using free-riding transactions

From the figures above we can see that the number of elderly and transportation travel in Seoul is concentrated during the daytime. So, the study excluded major commuting time range in order to explain the distribution of the daytime population related to the demand for non-working activities. Kang&Namgung(2017) studied elderly travel pattern is concentrated between 10 am to 5 pm. As for the nighttime, according to the 2014 survey of living hours released by Statistics Korea, the average bedtime for senior citizens aged over 65 was 10:11 pm and the wake-up time was 5:09 am. Therefore, according to the results of the living hours report, the nighttime for the elderly was set to between 11:00 pm to 4:59 am, and daytime was also set by the same time range, which from 11:00 am to 4:59 pm⑤. Yi&Choi(2018) analyzed the correlation between the average de facto population from 11:00 pm to 4:59 pm for a year in 2017 and the Census population of Seoul in 2016 and found that the Pearson correlation coefficient in the administrative dong unit has a high correlation of 0.81 between the de facto population in the nighttime and the resident population in the administrative dong unit.

2. Data

Demography is the study of the static and dynamic aspects of the population (Becker, 2008). Static aspects of a population include characteristics of observing a constantly fluctuating population at a point in time. Static population estimation is classified into de jure population and de facto population [Table 3. 1]. UN(1991) defined de jure population as individuals' location, which recorded to a geographical area based on the place of residence. And the de facto population is a concept under which individuals are recorded to the geographical area where they were present at a specified time. UN(2008) recommended using the 'service population', which is in line with the de facto population and it is relevant where a significant proportion of the population providing or using services

⑤ To analyze the robustness of the time zone, when analyzed with the elderly de facto population from 10 am to 5:59 pm in 2018 the result has an explanatory power of 67%, it can be said that the timeline from 11 am to 4:59 pm are robust.

in an area are not usual residents of that area. Here, the service population is the population that needs the service in the city from the perspective of the consumer and it is a different concept from the de jure population(residents) who cannot represent the actual population active in the city.

[Table 3. 1] Type of static population

Static population	De jure population	De facto population
Definition	An individual's location is recorded to their place of residence on Census day	An individual's location is recorded to where the person is present at the time
Characteristics of population	Population Census data	Mobile network metadata
Data source	National complete enumeration	LTE signal data of mobile phone users
Frequency and timeliness	Every 5 years	An hourly basis
Cost to collect data	Enormous budget is required	Routinely collected from the mobile phone network

To identify the everyday routine of the elderly, the de facto population data of Seoul was used. The data estimate the number of the present population by gender and age every five years range in the administrative unit on an hourly basis. The data can be explained as people who not only reside in Seoul but also temporarily visit Seoul for work, tourism, medical care, education, and shopping to generate administrative demand (Won, 2018).

The estimation method of the de facto population was estimated by the statistical method by merging Long Term Evolution (LTE) signal data of Korea Telecom (KT) telecom[6] company with public data of the Seoul Metropolitan Government. Since de facto population data collects data based on the LTE signal, all time and space information are recorded regardless of whether the phone is used or not, unless the mobile phone is turned off. Data based on the location of mobile devices could potentially become one of the most exciting new sources of information for urban analysis. And it is open to the Seoul Open Data Plaza[7] run by the Seoul Metropolitan Government. Due to the low mobile phone subscription rate among those under 10 and over 80 years of age, the number of these age groups is replaced by the estimated results of age between 10 to 14 and 70 to 79 years of age groups respectively.

When comparing the residence registration population(de jure population) with the de facto population of Seoul in 2018[table 3.2], the number of de facto populations in their 20s was about 318,600 (22%) more than the number of the resident population. And the excess of de facto populations aged over 65 was 381,250 (27%). This means that there are 27% more people in elderly people who are active in different places in Seoul from their residential areas. Thus, this paper notes the comparatively high number of active people in over 65 compared to other younger ages who have the characteristics for the regular mobility such as employment and education.

[Table 3. 2] Residence registration population and mean of de facto

[6] One of the oligopolistic network providers in South Korea
[7] https://data.seoul.go.kr/dataVisual/seoul/seoulLivingPopulation.do

population in Seoul, 2018

2018	20s	30-49	50-64	Over 65	Total population
Residence registration population	1,449,790	3,139,144	2,220,903	1,410,297	9,765,623
De facto population	1,768,390	3,622,804	2,278,807	1,791,547	11,088,670
Excess of de facto population	318,600	483,660	57,904	381,250	1,323,047
Excess ratio	22%	15%	3%	27%	14%

Currently, the Seoul Open data plaza is only available for download up to the age of 70 with a 5-year-old unit. But on the Seoul Big data campus⑧, it is possible to obtain up to the age of 80 with the 5-year-old unit. However, there is a strict regulation that raw datasets cannot be taken out and only results of statistics and images can be taken out because of the data privacy issue. Thus, the de facto population data used as the dependent variable was obtained from the Seoul Bigdata campus and could not describe the table of elderly population counts on this paper.

3. Methods

1) Data preprocessing

In this study, data preprocessing was performed to extract the elderly population at a specific time zone from the de facto population of big data to be used as a dependent variable for

⑧ https://bigdata.seoul.go.kr/main.do

statistical analysis. De facto population data were preprocessed using the Python Pandas tool to eliminate the days affecting the daily activities such as special occasions like national holidays or weekends. First, to improve the accuracy of results by removing the outlier from the collected data, the study minimized the impact of special occasions. Also, the service facilities that the elderly routinely use are open only on weekdays and are not open on weekends. Thus, the study only considered the weekdays, considering the number of days from Monday to Friday, excluding the whole week of any public holidays. Therefore, the analysis was conducted on the elderly population for a total of 195 days in 2018.

Second, aggregate the certain age groups by administrative dong unit to identify and classify the data. Third, classify the time zone from the collected data and combine the time zone of daytime and nighttime.

Lastly, the ratio of the elderly population to the nonelderly was used to analyze the distribution of the elderly population.

2) Exploration Spatial Data Analysis

Collected variable datasets were regenerated as spatial data using some technique of geographical information system (GIS) and the associated availability of geocoded data. Spatial analysis using GIS is a method of analyzing geographical visualization techniques and visualized results to analyze patterns of temporal changes in spatial data. Geographic information studies accept geographical visualization techniques and exploratory data analysis methods Exploration spatial data analysis (ESDA) as an important methodology for developing new methods to analyze the temporal variation pattern of spatial data(MacEachren&Kraak, 2001). And geospatial visualization was performed to derive information by applying geospatial data to polygon data of Seoul using ESRI's ArcGIS 10.6.2.

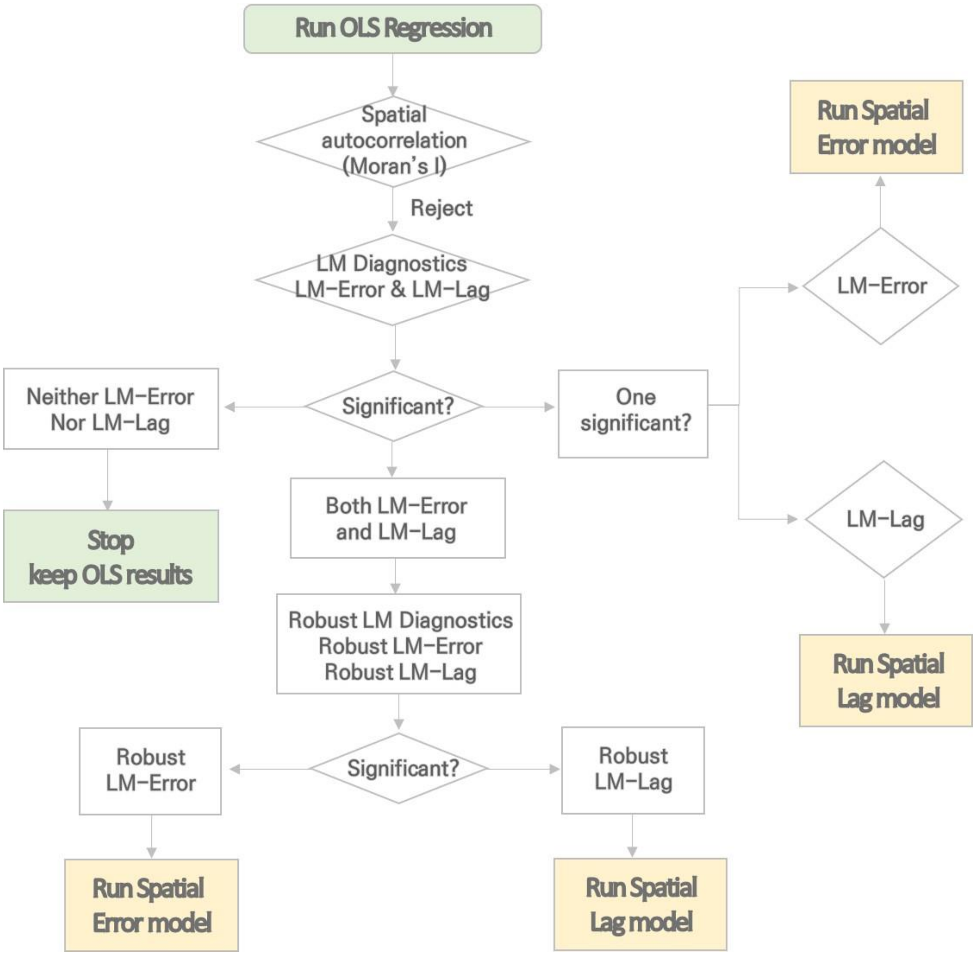
3) Spatial Econometric Models

(1) The spatial regression decision process

When the dependent variable is spatial data, it is necessary to check whether there are a statistically significant spatial dependence and heterogeneity through Moran's I analysis. Moran's I has a value between −1 and +1, and the closer to +1, the higher the spatial correlation. However, the spatial dependence may exist in the dependent variable, or it may violate the basic assumption of Ordinary Least Squares (OLS). Therefore, it is important to determine the location of spatial dependence through OLS analysis and diagnostics. [Figure 3. 5] shows an overview of the spatial regression decision process.

Based on the spatially constructed data, OLS including variables that can affect the mobility of the elderly by age are analyzed and this model is set as the baseline model. After analyzing the baseline model, it is checked once again whether spatial dependence exists through Lagrange Multiplier (LM) diagnostic tests. Here, the location of the dependence can be determined by the LM test. If the LM test is rejected, it can be judged to be spatially dependent, and if the null hypothesis is not rejected, the justification for analyzing the spatial analysis model disappears. So, it is possible to determine either the error or the lag model are the proper alternatives through the LM test. If the LM-Error model is significant, select Spatial Error Model (SEM) as an alternative model to compare with the standard model, and Spatial Lag Model (SLM) as an alternative model when an LM-Lag model is significant. And if neither rejects the null hypothesis from the LM test, it requires the consideration of the Robust form of the test statistics (Anselin, 2005).

After the analysis, compare the estimation results of the model. The statistical significance of the regression coefficients of the spatial error and lag model included in the alternative model is confirmed through a log-likelihood ratio test. If the spatial model loses statistical significance, stick with the OLS results. Otherwise, based on the baseline model, the spatial regression model that best shows the characteristics of the elderly population is selected by comparing the goodness-of-fit of each model.



(Source: Anselin, 2005; Lee&Noh, 2013)

[Figure 3. 5] Spatial regression decision process

(2) Spatial regression modeling

If spatial autocorrelation is found in the daytime mobility of the elderly through Moran's I analysis, spatial regression analysis is performed to control this. Spatial regression analysis uses SLM and SEM models. If there is no spatial autocorrelation, an OLS model is constructed, and in the case of spatial autocorrelation, an SLM model and an SEM model are constructed for comparative analysis.

The OLS model is as follows in [Equation 4. 1]:

[Equation 4. 1]

$$Y = X\beta + \mu$$
$$\mu \sim N(0, \sigma^2)$$

Here, Y is the dependent variable, X is the independent variable, β is the parameter, and μ is the error term.

The SLM directly reflects the spatial autocorrelation of dependent variables in the model. The SLM model is as follows in [Equation 4. 2]:

$$Y = \rho WY + X\beta + \varepsilon \qquad \text{[Equation 4. 2]}$$
$$\epsilon \sim N(0, \sigma^2 I_n)$$

Y is the dependent variable, X is the independent variable, W is the spatial weight matrix, ρ is a parameter of the spatial weight matrix, β is the parameter, and ε is the error term.

The SEM model is used to control the autocorrelation of the error term when it appears that the spatial dependency exists in the error. The SEM model is as follows in [Equation 4. 3]:

$$y = X\beta + \mu \quad \mu = \lambda W\mu + \varepsilon$$
$$\varepsilon \sim N(0, \sigma^2 I_n)$$
[Equation 4. 3]

Y is the dependent variable, X is the independent variable, W is the spatial weight matrix, λ is a parameter of the spatial weight matrix, β is the parameter, and ε is the error term.

(3) Model selection and validation

If the dependent variable has spatial autocorrelation, the use of the OLS method will cause a problem with the estimated bias of the regression coefficients. Accordingly, this study used a spatial econometric model to consider spatial dependence. If spatial dependence exists, it can be divided into the spatial lag model and spatial error model that control spatial dependence, and the most optimal model is determined through goodness-of-fit tests.

ChapterⅣ. Data Construction and Descriptive Statistics

1. Data Construction

1) Dependent variable

To identify the daily activities of the elderly, the de facto population data of Seoul was used. The characteristics of elderly mobility can be easily seen by comparing the distribution of the population by dividing the daytime and nighttime hours. Daytime is a time zone where we can get a glimpse of the mobility of daily activities of the elderly and the facilities mainly used by the elderly are open during the daytime.

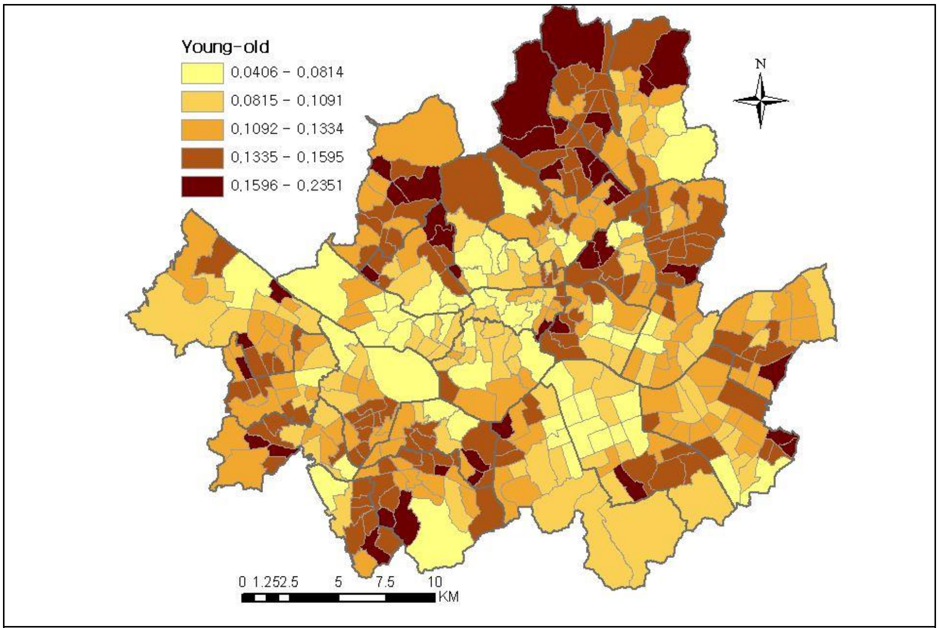
The elderly were subdivided into the total-old(aged over 65) group, young-old(aged 65 to 74) group, and old-old(aged over 75) group. The age composition of the elderly population has a great impact on the demand for welfare and leisure choice for the elderly (Jeong et al., 2017). Until the age of 75, it is a period when there is a high desire for active social participation and leisure after retirement and it is relatively healthy. However, after the age of 75, there is a high desire for protection rather than for social participation and leisure as daily life's difficulties slowly emerge and the condition of function decreases.

The ratio of each elderly group to nonelderly was used as an index to be used to analyze the spatial distribution of the elderly population. Indicators related to the aged population include the aging index, the aging dependency, the density of the aged population, and the proportion of the aged population (Jeong&Jeon, 2013). In the case of the density of the aged population, the size of the administrative dong is very different, and the proportion of the aged population that divides the aged population by the total number of populations is overlapping of the aged population in the total population. Therefore, in this study, the number of elderly people in the daytime period was divided by the number of non-aged people in the same time period in order to compare the mobility factors between the elderly and non-aged people.

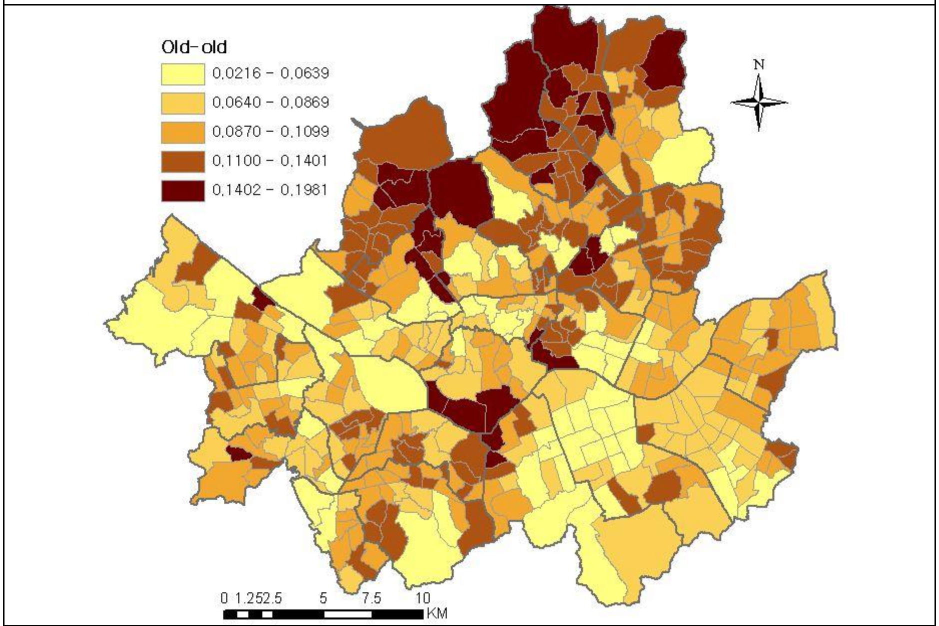
[Table 4. 1] Summary of dependent variable

Type	Variable	Unit of variables	Year	Source
Dependent variable	Total-old	(Aged 65+ / 0-64 de facto population) at 11:00 to 16:59	2018	Seoul Bigdata Campus
	Young-old	(Aged 65-74 / 0-64 de facto population) at 11:00 to 16:59	2018	Seoul Bigdata Campus
	Old-old	(Aged 75+ / 0-64 de facto population) at 11:00 to 16:59	2018	Seoul Bigdata Campus

[Figure 4.1] shows the spatial distribution of the elderly groups during the daytime. Each mapping is the ratio of the elderly per nonelderly population.



a. Young−old (65−74)



b. Old−old (75+)

[Figure 4. 1] Spatial distribution of Young−old and Old−old

2) Variable selection

Based on the previous studies, the urban environment factors affecting the elderly people's daytime mobility are classified into the following six indicators as below [Table 4.2], which are leisure welfare accessibility, medical service accessibility, neighborhood leisure services, transportation indicator, land use indicator, and demographic indicator.

(1) Leisure welfare accessibility

Leisure welfare facilities for the elderly are operated by the public to provide a physical environment and support individual leisure activities. The factors of the elderly leisure welfare facilities, which provide various services and information for the promotion of social welfare of the elderly were considered as prime determinants of this research. Kim&Kang(2017) empirically examined the types of leisure facility utilization for the elderly in urban areas: 59.4% of senior centers, 32.2% of elderly welfare centers, 24.5% of other welfare facilities, 13.1% of public leisure facilities, and 5.3% of private leisure facilities. Likewise, they have traditionally served as a major destination facility for many elderly populations. In addition to the elderly leisure welfare facilities that provide welfare services only for the elderly, social welfare centers also provide services welfare services for the elderly to prevent and solve welfare problems in the community by a regional base without distinguishing age. Therefore, facilities were considered as variables.

(2) Medical service accessibility

According to the Health Industry Development Institute's Analysis of personal expenditure medical expenses for the elderly aged over 65, the share of medical use of the elderly among total medical use increased by 11.6% in 2011 compared to 2010, increasing an annual average of 10.2%. As described above, because the elderly have a high demand for health and medical services (Han&Lee, 2015; Go&Lee, 2017), the types of hospitals are classified in detail: general hospitals, hospitals, and Korean medical clinics. Because this study concerns only the daytime visits for the medical facilities, home healthcare services such as nursing homes and daycare centers are not considered. According to the Korea Health Industry Development Institute, most of the elderly were using nearby clinics, and more patients visited Korean medical clinics than general hospitals. Similarly, Go&Lee(2017) found Korean medical clinics acted as a positive variable for attracting the travel of the age groups of 65-69, 70-74, and over 75. So, Korean medical clinics were included. And in this study, the concept of hospitals was considered regarding the number of sickbeds. Medical centers accommodating over 100 of sickbeds were set to general hospitals, and with over 30 of sickbeds were set to hospitals. And medical clinics accommodating under 30 sickbeds were not considered.

(3) Neighborhood leisure services accessibility

In recent years, it has been pointed out that the role and function of the welfare facilities for the elderly such as leisure, jobs, and care services have become ambiguous as the providers of elderly leisure services have been customized and diversified (Won&Choi, 2015). The variables here were selected taking into account the changing social needs of the elderly.

Han&Lee(2015) analyzed the purpose of travel for the elderly between different time zones. At 9~12 pm, shopping, leisure, and others were the major purpose of using public transportation for the elderly. Likewise, several studies indicated that retail environments increased the travel and density of the elderly (Han&Lee,2015; Go&Lee, 2017; Yi&Choi, 2018). Traditional markets are the main leisure place, as a dense area for the elderly during the day and night time (Yi&Choi, 2018) Also, the purpose of travel of the elderly was concentrated in the traditional market rather than large commercial facilities such as department stores (Han&Lee, 2015). However, Yi&Choi (2018) found that the accessibility of the department store increased the elderly concentration in both day and nighttime. Seniors who have an interest in health and participate in sports programs are increasing.

Due to the diversification of the needs of the elderly people's leisure, the number of elderly people who are using new leisure programs runs other facilities from the existing welfare facilities is also increasing. The number of elderly people participating in sports greatly increased and sports items enjoyed by the elderly also diversified from 4 in 2009 to 15 in 2014(Kim, 2015). Besides, recently, among the elderly, interest in dancing such as yoga and dance sports has increased. The Seoul Library plays a role in preparing silver generations to participate in social reading and discussion programs as a lifelong education (Lee, 2017).

(4) Transportation indicator

Kang&Namgung(2018) found the most common means of transportation used by the elderly are walking, passenger car, bus, and subway. The ratio of using public transportation such as buses and subways from the elderly is higher than that of the non-elderly people. And in the case of cars, the usage rate decreases with aging. Go&Lee(2017) studied the number of parking lots indicated as a positive factor for the young-old(aged 65-69), subway accessibility was more attractive for the old-old(aged over 75).

(5) Land use indicator

Land use indicators were added to identify the distribution of daily life of the elderly population in a certain land use environment. The green space including parks increased the travel of the elderly (Han&Lee,2015; Go&Lee,2017).

The green area is the space including the parks and green space. The elderly people who spend time in urban parks are high, so the most representative park such as Topgol Park and Jongmyo Park is often referred to as Silver Park. On the other hand, Lee et al. (2014) analyzed that the higher the proportion of the elderly without income and lives alone, the more vulnerable to climate change such as heatwaves. Therefore, if a green area is prepared, it will be a shelter to avoid the heat, and it will help to improve the thermal vulnerability of the elderly by lowering the temperature of the surrounding environment.

And as commercial facilities, traditional markets, and department stores influenced the travel of the elderly (Han&Lee,2015; Yi&Choi, 2018). Thus, commercial and green areas were expected to increase the distribution of the elderly population.

(6) Demographic indicator

Most studies indicated that the activity radius of the elderly tends to move around the dong area and prefer to stay in their residence (Hong, 2019), location of the residence will play a significant role in the actual location of the elderly. As a control variable, the proportion of the nighttime elderly population was considered as a proxy for the resident population.

[Table 4. 2] Summary of Explanatory Variables

Type	Variable	Unit of variables	Year	Source
Leisure welfare accessibility	Elderly welfare center	Number of elderly welfare centers in Dong	2018	Seoul open data plaza
	Senior center	Number of senior centers(경로당) in Dong	2018	Seoul open data plaza

	Senior class	Number of senior classes (노인교실) in Dong	2018	Seoul open data plaza
	Social welfare center	Number of social welfare centers in Dong	2018	Seoul open data plaza
Medical service accessibility	General hospital	Number of general hospitals (sickbeds > 100)	2018	Seoul open data plaza
	Hospital	Number of hospitals (sickbeds >30)	2018	Seoul open data plaza
	Korean medical clinic	Number of Korean medical clinics (한의원) in Dong	2018	Seoul open data plaza
Neighborhood leisure services	Retailers	Number of department stores, supermarkets, other large-scale retailers in Dong	2018	Seoul open data plaza
	Traditional market	Number of traditional markets in Dong	2018	Seoul open data plaza
	Public sports center	Number of public sports centers in Dong	2018	Seoul Bigdata campus
	Library	Number of libraries in Dong	2018	Seoul open data plaza
	Cultural center	Number of museums, galleries, and cultural centers in Dong	2018	Seoul open data plaza

Transportation indicator	Subway station	Number of subway stations in Dong	2018	Seoul open data plaza
	Bus stop	Number of bus stops in Dong	2018	Seoul open data plaza
	Road ratio	Road area(㎡)/Dong area(㎡)	2016	Seoul open data plaza
Land use Indicator	Commercial area ratio	Commercial area(㎡)/Dong area(㎡)	2018	Seoul open data plaza
	Green area ratio	Green area(㎡)/Dong area(㎡)	2018	Seoul open data plaza
Demographic Indicator	Proportion of nighttime elderly	(De facto population aged over 65yrs / De facto population of total ages) at 23:00pm to 4:00am	2018	Seoul open data plaza

2. Descriptive statistics

The descriptive statistics of the explanatory variables used in this study are as follows:

[Table 4. 3] Descriptive statistics

Type	Variable	Old-Old (75+)				
		N	Min	Max	Mean	SD
Dependent variable	Proportion of daytime Total-old	424	0.0632	0.3834	0.2162	0.0566
	Proportion of daytime Young-old	424	0.0412	0.2037	0.1188	0.0293
	Proportion of daytime Old-old	424	0.0048	0.1890	0.0948	0.0286
Leisure welfare accessibility	Elderly welfare center	424	0	1	0.19	0.40
	Senior centers	424	1	34	7.07	4.76
	Senior class	424	0	5	0.97	1.06
	Social welfare center	424	0	4	0.25	0.51
Medical service accessibility	General hospitals	424	0	2	0.13	0.36
	Hospitals	424	0	6	0.50	0.92
	Korean medical clinic	424	0	83	8.67	8.20
Neighborhood leisure services	Retailers	424	0	16	1.08	1.66
	Traditional market	424	0	11	0.73	1.27
	Public sports center	424	0	11	0.96	1.60
	Library	424	0	33	3.18	2.61
	Cultural facilities	424	0	23	0.57	2.10
Transportation indicator	Subway station	424	0	4	0.66	0.84
	Bus stop	424	1	99	20.38	13.74
	Road ratio	424	0.02	0.34	0.18	0.07
Land use indicator	Commercial area ratio	424	0	1	0.05	0.13
	Green area ratio	424	0	0.85	0.15	0.18
Demographic indicator	Proportion of Nighttime Elderly (65+)	424	0.04	0.16	0.09	0.02

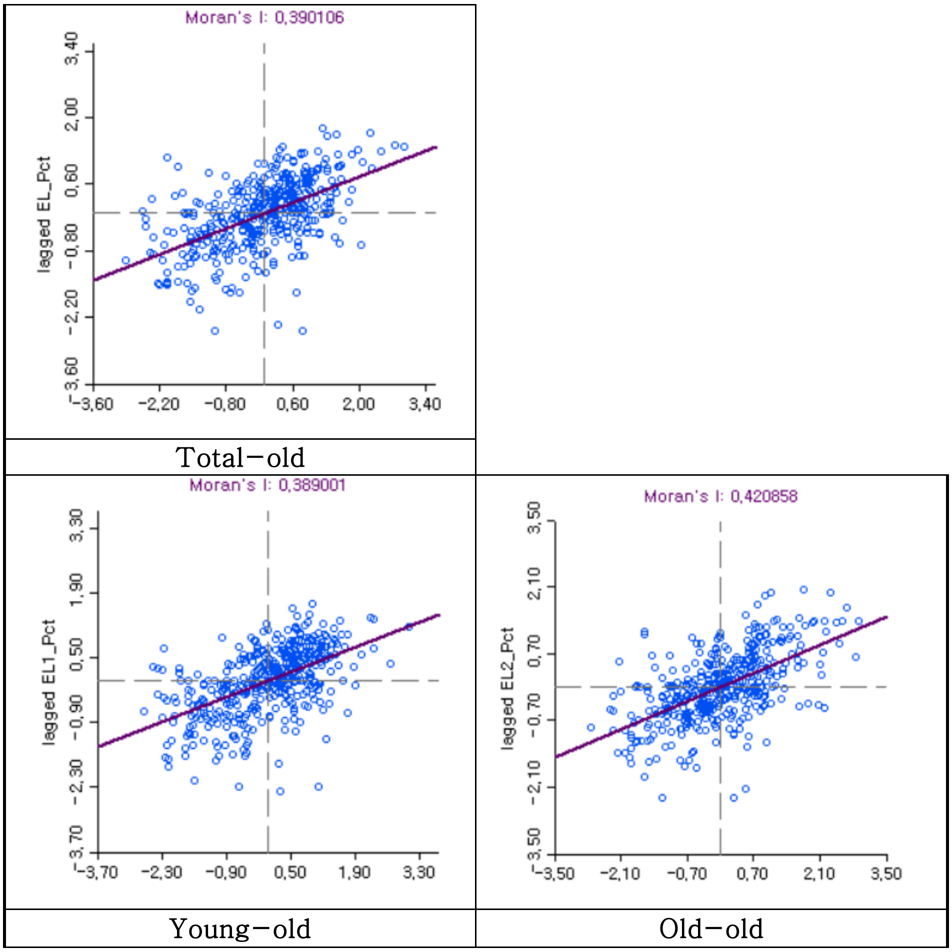
Chapter Ⅴ. Results of analysis

1. Spatial autocorrelation of the elderly

1) Exploring spatial autocorrelation

Through the spatial distribution mapping of the elderly population, which was discussed earlier, the population distribution of the elderly in Seoul was demonstrated. Here, spatial autocorrelation was analyzed to grasp the spatial association among the elderly population. In general, spatial autocorrelation is measured using Moran's I or Geary's C(Rhee, 2016). The formulas for calculating the two indices differ somewhat, but the results are almost similar (De Jong et al., 1984). In this research, Moran's I was calculated to measure the spatial autocorrelation level of the elderly population at the global level. In order to calculate spatial autocorrelation, this study constructed a spatial adjacency matrix using the Rook contiguity (Anselin, 1995) based on spatial proximity.

As a result of calculating Global Moran's I for spatial distribution patterns in each age group of the elderly, Global Moran's I value of the total-old was 0.3901, young-old was 0.3890, and old-old was 0.4209, indicating that spatial autocorrelation exists [Figure 5.1].



[Figure 5. 1] Global Moran' s I index for the elderly

Therefore, the first hypothesis of this study that the distribution of the elderly daily mobility in Seoul is spatially autocorrelated was confirmed that the spatial distribution of the elderly population per the non−elderly population is distributed in adjacent areas with similar age groups.

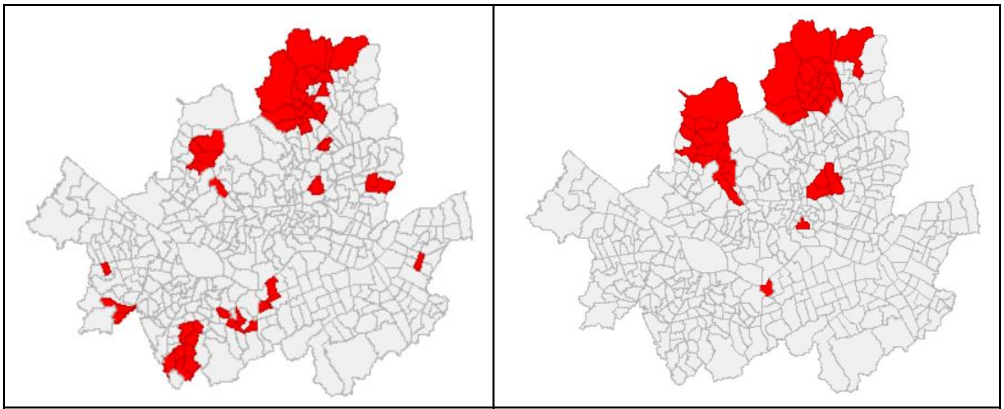
2) Spatial patterns of the elderly

As discussed in the previous section, when analyzing spatial association, Global Moran's I index is used to determine whether there are distinct spatial clusters across the entire study area. However, since the Global Moran's I index represents the spatial autocorrelation of the entire study area as a single value, it is not possible to identify the local structure of the spatial association. In other words, it is not possible to know what value a specific region represents the spatial autocorrelation, or how much a particular area is affecting the spatial autocorrelation of the whole region.

Thus, the Local Indicator of Spatial Association (LISA) index proposed by Anselin (1995) is used to measure spatial association at the local level. LISA is judged as positive autocorrelation when the weighted average of the values of a specific region and the values of neighboring regions are similar to each other. Conversely, if the difference between the value of a specific area and the weighted average value of adjacent areas is large, it is judged as a negative autocorrelation. Therefore, it is possible to determine the significance of spatial clusters having similar values around individual regions through LISA analysis and to extract local and unusual regions.

[Figure 5. 2] shows the results of the LISA of the ratio of the elderly population in Seoul. LISA indicates significant spatial clustering of similar values of the ratio of elderly per nonelderly. Z−score used a 95% significance level, which is greater than 1.96. And the result of mappings was extracted to represent the hot spot area of the elderly compared to the non−aged population. [Figure

5.2.a] shows the hotspot of Young−old, which is distributed in Gwanak−gu, Dongjak−gu, Geumcheon−Gu, and Guro−gu in addition to Gangbuk−gu, Dobong−gu, Eunpyeong−gu, and Nowon−gu. [Figure 5.2.b] show the hotspot is distributed in the northern part of the river and to the area around Dobong−gu, Gangbuk−gu, and Eunpyeong−gu.



a. Young−old	b. Old−old

[Figure 5. 2] Spatial clustering patterns of the elderly

2. Results of the Baseline Model

1) Results of the Baseline Model

The baseline model, which used OLS regression are analyzed and it is summarized by age as shown in [Table 5. 1]. Of the leisure welfare accessibility, the elderly welfare center was significant with total−old and old−old. And in the case of medical service accessibility, the general hospital was significant with young−old and old−old. And the Korean medical clinic was significant with all older ages. Also, the traditional market in neighborhood leisure services was significant with all elderly groups. The road ratio of transportation indicators was found to increase both total−old and young−old. In the land−use indicator, the commercial area ratio indicated a positive impact on all age groups. And the green ratio was significant with total−old and young−old. As a control variable, the nighttime elderly of the demographic indicator was significant for each age group of the elderly.

[Table 5. 1] Results of the baseline analysis

OLS		Total−old	Young−old	Old−old
Leisure welfare accessibility	Elderly welfare center	0.007*	0.0022	0.0064**
	Senior center	−0.0002	−0.0002	−0.0001
	Senior class	−0.002	−0.001	−0.0003
	Social welfare center	0.007	0.003	0.0027
Medical service accessibility	General hospital	0.008	0.005*	0.0055*
	Hospital	0.0004	0.001	−0.001
	Korean medical clinic	0.0006**	0.0003**	0.0002*
Neighborhood leisure services	Retailers	−0.0007	−0.0002	0.0004
	Traditional market	0.006***	0.0023**	0.0025**
	Public sports center	0.001	0.001	0.0007
	Library	−0.0005	−0.0005	−0.0002
	Culture	0.0003	−0.0006	0.0007

Transportation indicator	Subway station	0.002	0.0004	0.0016
	Bus stop	−0.0002	−0.0001	−0.00008
	Road ratio	0.071*	0.084***	−0.005
Land use indicator	Commercial area ratio	0.057***	0.034***	0.026***
	Green area ratio	0.027***	0.02***	0.008
Demographic indicator	Nighttime Elderly	0.007***	0.0039***	0.0036***

*: p-value<.1, **: p-value<.05, ***: p-value<.01

2) Diagnostics for the Baseline Model

Regarding measures of fit, R−squared (R^2) of total−old, young−old, and old−old variable shows results of 0.677, 0.701, and 0.703, indicating the explanatory power with approximately 67%, 70%, and 70%, respectively. Also, the Variance Information Factor (VIF) for each variable in the model was less than 5. In other words, there was no Multi−Collinearity in the baseline model.

Based on the Gaussian Markov theorem, the baseline models were determined whether the regression analysis complies with the assumptions of normality, homoskedasticity, and spatial independence [Table 5. 2]

For the results of 'Total−old', the Jarque−Bera statistic for diagnosing the normal distribution of the error term was 73.606 (p=0.000), showing strong non−normality. And the Breusch−Pagan statistic for verifying homoscedasticity was 95.081 (p=0.000), indicating that heteroscedasticity exists. In addition, when looking at the statistical values of LM−Lag and LM−Error, which determines whether the dependent variable and the error term are spatially dependent, the null hypothesis was rejected at the 1% level of both LM−Lag and LM−Error. This spatial dependence can be solved by using SLM and SEM to analyze including the spatial weighted matrix.

Secondly, in the results of ‘Young−old’, the Jarque−Bera statistic was 38.034(p=0.000), showing significance with non−normality. And the Breusch−Pagan statistic was 40.327(p=0.000), indicating that heteroscedasticity exists. Also, when looking at the statistical values of LM−Lag and LM−Error, which determines whether the dependent variable and the error term are spatially dependent, the null hypothesis was rejected at the 1% level of both LM−Lag and LM−Error. This spatial dependence can be solved by using SLM and SEM to analyze including the spatial weighted matrix.

Lastly, in the results of ‘Old−old’, the Jarque−Bera statistic for diagnosing the non−normality of the error term was 69.284(p=0.000), showing strong significance. And the Breusch−Pagan statistic for verifying heteroscedasticity was 76.27(p=0.000), indicating that heteroscedasticity exists. Moreover, when looking at the statistical values of LM−Lag and LM−Error, which determines whether the dependent variable and the error term are spatially dependent, the null hypothesis was rejected at the 1% level of both LM−Lag and LM−Error. This spatial dependence can be solved by using SLM and SEM to analyze including the spatial weighted matrix.

[Table 5. 2] Diagnostic tests for the Baseline Model

OLS Diagnostics		Total−old	Young−old	Old−old
Measures of fit	Adjusted R^2	0.677	0.666	0.602
	AIC	−1649.6	−2149.69	−2129.27
	SC	−1572.66	−2072.75	−2052.32
	Log likelihood	843.802	1093.85	1083.63
Normality	Jarque−Bera	73.606***	38.034***	69.284***
Homoscedasticity	Breusch−Pagan	95.081***	40.327***	76.27***
	Koenker−Bassett	58.426***	26.118*	49.48***
Spatial independence	Lagrange Multiplier (lag)	13.4899***	19.5208***	36.0554***
	Lagrange Multiplier (error)	10.9839***	10.1212***	47.9925***
	Robust LM (lag)	6.2412**	11.4813***	8.5546***
	Robust LM (error)	3.7352*	2.0816	20.4916***

*: p−value<.1, **: p−value<.05, ***: p−value<.01

Since all models rejected the null hypothesis about the spatial independence of dependent variables and error terms at the level of 1% for LM diagnostics, proceed to the Robust forms of test statistics (Anselin, 2005).

Robust LM diagnostics go with the model with more significance than the other. In the Total−old case, the null hypothesis about the spatial independence of dependent variables and error terms is rejected at the level of Robust LM−Lag at a 5% level and Robust LM−Error level at a 10% level. Since the significance level for the

Robust LM−Lag was higher than the LM−Error, the Spatial Lag Model was finally selected to analyze the estimated regression coefficient of the total−old.

In the case of the young−old, the Robust LM−Lag was found to be at a 1% significance level, but the Robust LM−Error was not significant. Therefore, it can be concluded that a Spatial Lag Model is used to establish a regression model for factors affecting the number of young−old people in the region.

In the case of old−old, the null hypothesis is rejected at the 1% significance level for both Robust LM−Lag and Robust LM−Error. In this case, a model with a higher statistic is selected (Anselin, 2005). Thus, the Robust LM−Error was selected because the statistical value of Robust LM−Error(20.4916) is higher than that of Robust LM−Lag(8.5546).

3. Model selection for spatial regression

The goodness−of−fit of the spatial regression model is tested by R^2 , log−likelihood (LL), Akaike Information Criterion (AIC) (Lee& Noh, 2013). In general, the spatial regression model increases the R−squared and LL, and the AIC decreases, which means that the fit of the model is improved. The comparison of goodness−of−fit is shown in [Table 5.3]. In all models, the R−squared value and LL increased in the spatial regression analysis and the AIC decreased, compared to the baseline model.

[Table 5. 3] Comparison of goodness-of-fit

Elderly	Model		Measures of goodness-of-fit		
			R^2	LL	AIC
Total-old (65+)	BM	OLS	0.677	843.802	-1649.6
	SRM	SLM	0.701	850.438	-1660.88
		SEM	0.703	849.808	-1661.62
Young-old (65-74)	BM	OLS	0.666	1093.85	-2149.69
	SRM	SLM	0.696	1103.57	-2167.15
		SEM	0.693	1099.53	-2161.05
Old-old (75+)	BM	OLS	0.602	1083.63	-2163.02
	SRM	SLM	0.653	1101.51	-2082.02
		SEM	0.679	1108.87	-2102.78

*BM (Baseline Model)
*SRM (Spatial Regression Model)
*AIC (Akaike Information Criterion)
*LL (Log-Likelihood)

From the previous model selection process comparing the robust LM diagnostics and the significance of the model, the selected model of the total-old is SLM, of young-old is SLM, and of old-old is SEM.

4. Results of Spatial regression model

[Table 5.4] below compares the results obtained from the results of the selected spatial regression models on daytime elderly mobility.

First, the results of the total-old are explained as follows. Of the leisure welfare accessibility variables, the elderly welfare center was shown to have an impact on the elderly daytime mobility.

Korean medical clinic showed a positive effect on medical service accessibility, and the traditional market showed significant as well. An increased road ratio was found to increase elderly mobility. And commercial area density and green area density were found to increase the elderly. The nighttime elderly population of the demographic indicator was found linked to an increased daytime elderly population.

Regarding classified age groups, results of young-old and old-old are compared and they were different from the impacts on the mobility of the elderly in each age. Young-old was found to have a positive effect in social welfare centers, but for the old-old, it was elderly welfare centers.

Of medical service accessibility, the Korean medical clinic was significant in both young-old and old-old, but a general hospital was found to increase only young-old. In reviewing the literature (Han&Lee, 2015; Kang&Namgung, 2018), a good medical environment acts as a factor of travel for the elderly who have high rates of hospital visits. Korean medical clinics were shown to lead both young-old and old-old, in accord with Go&Lee (2017) indicating Korean medical clinics have a positive impact on non-commuting travel aged 65-69, 70-74, and over 75 have. In the traditional market, both age groups were found to be significant variables, supporting the results of studies that were significant in the daytime travel of the elderly (Han&Lee, 2015) and population-dense areas (Yi&Choi, 2018). It is interesting to note that the public sports center was linked with more young-old. (Kim, 2015).

The result of the road ratio support previous research into the rate of vehicle traffic was 13.2% in the young−old and 8.5% in the old−old (Kang&Namgung, 2017) Commercial area ratio, green area ratio, and nighttime elderly were both significant. The commercial area supports the results that shopping is predominant purpose of travel of the elderly between 9 am to 3 pm(Han&Lee,2015), and Yi&Choi(2018) interpreted it as the shopping behavior of the elderly has changed from the increase of active seniors with high purchasing power even after retirement. Green area ratio is a place to enjoy among the elderly during the daytime (Han&Lee, 2015). Nighttime elderly is the residential population as a control variable and it has positive impacts on the daytime elderly.

[Table 5. 4] Results of selected models

Selected models		Total−old (SEM)	Young−old (SLM)	Old−old (SEM)
Leisure welfare accessibility	Elderly welfare center	0.007*	0.0022	0.056**
	Senior center	−0.0001	−0.0001	−0.00006
	Senior class	−0.001	−0.0009	0.0016
	Social welfare center	0.007	0.005*	0.0016
Medical service accessibility	General hospital	0.008	0.005*	0.0032
	Hospital	−0.0001	0.0005	−0.001
	Korean medical clinic	0.0006**	0.0003**	0.0002*
Neighborhood leisure	Retailers	−0.0007	−0.0002	0.000004
	Traditional	0.006***	0.0021**	0.0016*

services	market			
	Public sports center	0.001	0.001**	0.0008
	Library	−0.0006	−0.0006	−0.0005
	Culture	0.0004	−0.0004	0.0007
Transportation indicator	Subway station	0.002	0.0005	0.0011
	Bus stop	−0.0002	−0.0001	−0.00008
	Road ratio	0.08**	0.087***	−0.02
Land use indicator	Commercial area ratio	0.053***	0.032***	0.021**
	Green area ratio	0.028***	0.02***	0.012**
Demographic indicator	Nighttime Elderly	0.007***	0.0037***	0.0033***
ρ (Rho)			0.096***	0.115***
λ (Lambda)		0.2188***		
R^2		0.704	0.701	0.696
AIC		1919.74	−1660.88	−2167.15
SC		1996.69	−1579.88	−2086.15
Log likelihood		−940.871	850.438	1103.57

*: p−value<.1, **: p−value<.05, ***: p−value<.01

ChapterⅥ. Conclusion

1. Summary and conclusion

The thesis aimed to analyze the spatial distribution of the elderly population during the daytime and to identify the daily urban environment factors affecting the daily mobility of the young−old and old−old.

The de facto population big data of Seoul in 2018, which were provided by the Seoul big data campus was used. And the elderly were classified by age: the young−old (aged 65 to 74 years old) and the old−old (aged over 75) to analyze the urban environment factors affecting the daytime mobility of the elderly. Also, by classifying the time zones from 11 pm to 4:59 pm as daytime and from 11 pm to 4:59 am as nighttime on weekdays, daytime during which leisure and social activities of the elderly are mainly performed was considered as a dependent variable.

The paper hypothesized leisure welfare accessibility and medical service accessibility positively affects the daytime mobility of the total−elderly. Among the leisure welfare accessibility and medical service accessibility, elderly welfare facility and Korean medical clinic were found to increase the mobility of total−elderly. When dividing the elderly into Young−old and Old−old, the study assumed daily urban environment factors affecting the young−old ages and old−old ages are different. The research hypothesized Young−old has a much larger active radius than Old-old and more active leisure services positively affect Young-old. Road ratio showed a positive effect only on the Young-old, not on the Old-old. And regarding on neighborhood leisure services, traditional market and public sports center were found to be positively significant on Young-old.

2. Implications

First, due to the recent enhancement of the health level of the elderly and the access to transportation, the activity radius is expanded. Thus, in some places, the existing residence and their activity area are different. To meet the elderly's daily patterns and physical characteristics, elderly-friendly urban infrastructure policy is needed to develop senior cultural space plans based on the de facto population of the elderly. Since 2014, the Seoul Metropolitan Government has been established as a customized cultural special street for the elderly around Jongmyo · Tapgol Park(종묘·탑골 공원), which is a representative area for the elderly and has been fostered as a center of silver economy and transformed into a place for sharing the culture between other generations. As such, a senior cultural space was created, and thus the spatial distribution of the daytime active areas of the elderly population identified in this study can be used as important information to create a special cultural space for the elderly.

Secondly, when the age of the elderly was classified, the Young-old and the Old−old showed different characteristics. Considering that the general hospital has positively significant, Young−old has a wider activity radius when they use medical service and uses sports centers to actively engage in leisure activities. Also, as the number of elderly drivers increases, it is necessary to improve the road infrastructure as well as to improve the driving culture for the elderly.

Thirdly, there is a difference in the preference of the leisure welfare facilities within the elderly. Elderly welfare facilities increase the old−old and social welfare facilities that increases the young−old. Elderly welfare center carries out welfare programs only for the elderly, the social welfare center supports an age−integrated program. Furthermore, this study suggests that organizing a program that responds to the changing needs of the Young−old.

3. Limitations

The dataset used in the paper is the de facto population, which is static population data. For those aged over 80 and under 10, the corrected value for the estimation of the population was used because of their low subscription rate for the cell phone signal.

The temporal scope of this study was limited that only one year as a single point was performed due to the limitations of collectible explanatory data. Future work needs to be carried out using the multiple years of the de facto population datasets.

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Appendix

[Appendix 1-1] Results of Total-old

Total-old		OLS	SLM	SEM
ρ (Rho)			0.096***	
λ (Lambda)				0.224***
	Constant	0.049***	0.034***	0.052***
Leisure welfare accessibility	Elderly welfare center	0.007*	0.007*	0.007*
	Senior center	-0.0002	-0.0001	-0.00008
	Senior class	-0.002	-0.001	-0.0009
	Social welfare center	0.007	0.007	0.005
Medical service accessibility	General hospital	0.008	0.008	0.006
	Hospital	0.0004	-0.0001	0.00097
	Korean medical clinic	0.0006**	0.0006**	0.0005**
Neighborhood leisure services	Retailers	-0.0007	-0.0007	-0.001
	Traditional market	0.006***	0.006***	0.006***
	Sports center	0.001	0.001	0.001
	Library	-0.0005	-0.0006	-0.0008
	Culture	0.0003	0.0004	0.0004
Transportation indicator	Subway station	0.002	0.002	0.002
	Bus stop	-0.0002	-0.0002	-0.0002
	Road ratio	0.071*	0.08**	0.071**
Land use indicator	Commercial area ratio	0.057***	0.053***	0.056***
	Green area ratio	0.027***	0.028***	0.028***
Demographic indicator	Nighttime Elderly	0.007***	0.007***	0.007***
Measures of fit	R^2	0.677	0.701	0.703

	AIC	-1649.6	-1660.88	-1661.62
	SC	-1572.66	-1579.88	-1584.67
	Log likelihood	843.802	850.438	849.808
Normality	Jarque-Bera	73.606***		
Homoscedasticity	Breusch-Pagan	95.081***	62.769***	62.64***
	Kosenker-Bassett	58.426***		
Spatial independence	Likelihood ratio		18.448***	14.31***
Lagrange Multiplier(lag)		13.4899***		
Robust LM(Lag)		6.2412**		
Lagrange Multiplier(error)		10.9839***		
Robust LM(Error)		3.7352*		

*: p-value<.1, **: p-value<.05, ***: p-value<.01

[Appendix 1-2] Results of Young-old

Young-old		OLS	SLM	SEM
ρ (Rho)			0.115***	
λ (Lambda)				0.205***
	Constant	0.023***	0.028***	0.037***
Leisure welfare accessibility	Elderly welfare center	0.0022	0.0022	0.0024
	Senior center	-0.0002	-0.0001	-0.0001
	Senior class	-0.001	-0.0009	-0.0008
	Social welfare center	0.003	0.005*	0.002
Medical service accessibility	General hospital	0.005*	0.005*	0.004
	Hospital	0.001	0.0005	0.0008
	Korean medical clinic	0.0003**	0.0003**	0.0002*
Neighborhood leisure services	Retailers	-0.0002	-0.0002	-0.0003
	Traditional market	0.0023**	0.0021**	0.0021**
	Sports center	0.001	0.001**	0.0012**
	Library	-0.0005	-0.0006	-0.0007
	Culture	-0.0006	-0.0004	-0.0004
Transportation indicator	Subway station	0.0004	0.0005	0.0005
	Bus stop	-0.0001	-0.0001	-0.00008
	Road ratio	0.084***	0.087***	0.083***
Land use indicator	Commercial area ratio	0.034***	0.032***	0.034***
	Green area ratio	0.02***	0.02***	0.02***
Demographic indicator	Nighttime Elderly	0.0039***	0.0037***	0.0038***
Measures of fit	R^2	0.666	0.696	0.693
	AIC	-2149.69	-2167.15	-2161.05
	SC	-2072.75	-2086.15	-2084.11
	Log likelihood	1093.85	1103.57	1099.527

정규성	Jarque-Bera	38.034***		
등분산성	Breusch-Pagan	40.327***	48.289***	39.97***
	Kosenker-Bassett	26.118*		
공간적 종속성	Likelihood ratio		19.459***	11.36***
Lagrange Multiplier(lag)		19.5208***		
Robust LM(Lag)		11.4813***		
Lagrange Multiplier(error)		10.1212***		
Robust LM(Error)		2.0816		

*: p-value<.1, **: p-value<.05, ***: p-value<.01

[Appendix 1-3] Results of Old-old

Old-old		OLS	SLM	SEM
ρ (Rho)			0.1**	
λ (Lambda)				0.42***
	Constant	0.023***	0.009***	0.023***
Leisure welfare accessibility	Elderly welfare center	0.0064**	0.0061**	0.056**
	Senior center	-0.0001	-0.0008	-0.00006
	Senior class	-0.0003	-0.0002	0.0016
	Social welfare center	0.0027	0.0029	0.0016
Medical service accessibility	General hospital	0.0055*	0.0045*	0.0032
	Hospital	-0.001	-0.001	-0.001
	Korean medical clinic	0.0002*	0.0002*	0.0002*
Neighborhood leisure services	Retailers	0.0004	0.0004	0.000004
	Traditional market	0.0025**	0.002**	0.0016*
	Sports center	0.0007	0.0006	0.0008
	Library	-0.0002	-0.0003	-0.0005
	Culture	0.0007	0.0007	0.0007
Transportation indicator	Subway station	0.0016	0.0016	0.0011
	Bus stop	-0.00008	-0.00008	-0.00008
	Road ratio	-0.005	-0.01	-0.02
Land use indicator	Commercial area ratio	0.026***	0.023**	0.021**
	Green area ratio	0.008	0.01**	0.012**
Demographic indicator	Nighttime Elderly	0.0036***	0.0033***	0.0033***
Measures of fit	R^2	0.602	0.653	0.679
	AIC	-2129.27	-2163.02	-2177.77
	SC	-2052.32	-2082.02	-2102.78
	Log likelihood	1083.63	1101.51	1108.87

Normality	Jarque-Bera	69.284***		
Homoscedasticity	Breusch-Pagan	76.27***	64.706***	51.848***
	Kosenker-Bassett	49.48***		
Spatial dependence	Likelihood ratio		35.749***	50.46***
Lagrange Multiplier(lag)		36.0554***		
Robust LM(Lag)		8.5546***		
Lagrange Multiplier (error)		47.9925***		
Robust LM(Error)		20.4916***		

*: p-value<.1, **: p-value<.05, ***: p-value<.01

국문 초록

서울시 주간 노인 인구 이동성의 영향요인에 관한 연구

-서울 생활인구 빅데이터를 사용하여-

고령화 현상은 인구학적 변동에만 국한되지 않고, 생활 환경의 변화, 더 나아가 노인들의 의식과 사회 구조의 변화로 이어지는 범세계적인 추세이다. 이처럼 과거에 비해 개선된 고령자들의 경제적, 신체적 여건에 따라 나이듦을 대하는 관점에 있어서도 많은 변화를 가져왔다. 특히 65세 이상을 하나의 단일 노인집단으로 간주하는 것은 신체적·경제적으로 능력이 향상된 고령자의 증가와 고령자 연령대에 따른 차이를 간과하게 만든다. 최근에는 젊은 노인(Young-old)들의 증가로 인해 새로운 경제활동의 주체로 고령자층을 바라보는 분위기가 확산되고 있다. 따라서 대중교통 접근성이 양호한 서울과 같은 대도시에서는 노인의 이동성 제약이 완화되어 활동반경이 넓어지면서 고령자 이동에 대한 공간적 제약이 감소되어 고령인구의 경제활동 참여율은 증가하고 도시 내 여가활동의 비중은 다양해지고 있다.

본 연구는 과거 주민등록지 중심으로 고령인구의 분포를 고려하였다면 고령인구의 여가 및 사회활동이 주로 이루어지는 주간시간대의 공간적 분포를 파악하고 이를 전기고령자(65세이상 75세 미만)과 후기고령자(75세 이상)으로 세분화하여 주간시간 노인인구의 이동성에 영향을 미치는 도시의 물리적 환경의 영향요인을 분석하는 데 목적을 둔다.

주간시간대 고령인구의 이동성에 영향을 미치는 요인이 연령대에 따라

다르게 나타날 것으로 가설을 세웠으며, 고령인구 집단 내에서도 전기고령자가 후기고령자에 비해 이동성이 더 증가할 것이라고 예상하였다.

모형분석은 2018년 서울시 생활인구 데이터를 토대로 수행되었다. 분석을 위한 기준 모형으로 일반회귀모형(OLS)을 설정하고 대안모형으로는 전역적 공간계량모형인 공간시차모형(Spatial Lag Model)과 공간오차모형(Spatial Error Model)을 설정하였다. 모형 분석 결과, 전기고령자의 주간시간 이동성을 증가시키는 요인들로 종합사회복지시설, 종합병원, 전통시장, 공공 운동시설, 도로율, 상업지역, 야간시간 고령자 수이며, 후기고령자의 경우는 노인복지시설, 전통시장, 상업지역, 야간시간 고령자 수가 영향을 미치는 것으로 나타났다. 이와 같은 결과는 연령통합적 복지시설을 선호하는 전기노인과 노인 위주의 복지시설을 선호하는 후기노인의 복시시설 선호도가 반영되었다고 볼 수 있다. 또한 전기 고령자의 경우 후기고령자에 비해 주간시간 이동 범위가 넓으며 이들의 새로운 여가문화의 활성화를 위한 특화된 여가활동 프로그램이 제안되었다.

본 연구는 도시 공간적 요소를 포함한 다양한 요소들이 고령자들의 이동성에 미치는 영향을 증명하였으며, 전기고령자와 후기고령자의 이동성에 영향을 미치는 도시환경요인은 차이가 존재함을 확인하여 연구 가설을 입증하였다. 인구의 유동성을 반영하는 생활인구 데이터를 활용하여 고령인구의 활동데이터를 통한 정책 효율성 제고 방안 모색하는 것이 필요하다. 현재 서울시에서 추진하고 있는 노인중심 문화공간 조성을 위해 노인들의 활동시간대 밀집지역을 대상으로 노인의 신체적 특성을 고려한 고령친화공원 조성의 정책 마련이 고려되어져야 할 것이다.

키워드: 고령 활동인구, 주간 시간 이동성, 영향 요인, 여가활동, 공간계량모형

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